

Concrete Performance with Hypo Paper Sludge and Hybrid Fibers

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Abstract: In India, modern activities necessitate the excessive use of plastic bags. Because plastic is not biodegradable, it takes years to disintegrate. Poly-ethylene is the primary component of plastic bags. When polyethene is burned, it emits carbon dioxide as a byproduct, contributing to global warming. This study looks at how integrating hypo paper sludge (HPS) and hybrid fibres affects the performance of concrete. Hypo paper sludge, an industrial waste product, was assessed for its potential as a partial substitute for cement in order to improve sustainability and minimise environmental effect. In addition, hybrid fibres, which combine synthetic and natural fibres, were used to increase the mechanical qualities of concrete. A complete experimental programme was used in the study, which included compressive, tensile, flexural, and durability testing. The results showed that using HPS up to a specific amount did not significantly reduce concrete strength, although hybrid fibres increased toughness and fracture resistance. The ideal mix design struck a balance between mechanical performance and sustainability, implying that the combination of hypo paper sludge and hybrid fibres is a feasible option for greener and more robust concrete constructions. This research provides the path for further investigation into the utilisation of industrial byproducts and novel fibre technologies in concrete applications. In this study, we evaluate the compressive strength of concrete with fine aggregate substituted by 3% (plastic fibres) and 1% (steel fibres) to M20 grade control concrete. Iron fibres with widths ranging from 1-2 mm are used in a preset amount to compensate for the strength loss caused by replacement. Some of the keywords are plastic waste, iron fibres, hypo-sludge, strength, cement, and concrete (M20). Compressive strength is the most important mechanical attribute of concrete, and it is evaluated on 150 mm cubes with 10% hypo sludge

replacing cement weight. The compressive strength is measured over 28 days and the results are analyzed.

Keywords: Hypo sludge, Steel fibres, Plastic fibres, Ordinary Portland cement (O.P.C.), Compressive strength.

1. Introduction

Interlocking Concrete Block (ICB) is a specialised technology used globally to create durable pavements in areas where traditional construction methods may not be suitable due to various operational and environmental factors (1). ICB consists of solid, unreinforced pre-cast cement concrete paver blocks used in a range of traffic paving applications (2). Introduced in India a decade ago for specific needs such as pathways and parking spaces, ICBP is now widely used for various applications. It's difficult to imagine a more adaptable building material than concrete, which is the chosen choice where strength, durability, impermeability, fire resistance, and absorption resistance are necessary [1], [2]. Compressive strength is typically used to assess the overall quality of concrete, and it is generally accepted that improvements in compressive strength also translate to improvements in all other qualities. Consequently, compressive strength is the main focus of most strength research (6–10). Although the purpose of concrete mixes is to get the required compressive strength within a given time frame, flexural strength is frequently important during the

concrete manufacturing process. Hypo sludge, a waste product from the paper industry, has a lot of potential in this area. It is commonly known that adding hypo sludge to concrete greatly improves its rheological characteristics. [3]–[5].

Hypo Paper Sludge" refers to the residue left behind after the de-inking process in paper recycling. As the name suggests, it's a sludgy substance, often dark in color, and composed of various materials like ink, coatings, and other contaminants removed from the paper during recycling. The de-inking process is crucial in paper recycling because it separates the ink from the paper fibers, allowing the fibers to be reused to make new paper products. However, this process generates a significant amount of waste in the form of hypo paper sludge [6], [7]. Managing hypo paper sludge presents environmental challenges. Disposal methods must be carefully considered to minimize its impact on the environment. Historically, some paper mills have disposed of hypo paper sludge in landfills, but this approach has drawbacks. The sludge can contain harmful substances such as heavy metals and toxic chemicals, which could leach into the soil and

water, posing risks to ecosystems and human health [8]–[10]. To address these challenges, alternative disposal and utilization methods have been explored. One approach is to incinerate the sludge to generate energy, although this raises concerns about air pollution and greenhouse gas emissions. Another option is to treat the sludge to remove contaminants and then use it as a soil amendment or in construction materials [11]–[15]. Research and innovation continue to play a vital role in finding more sustainable solutions for managing hypo paper sludge. By developing efficient recycling technologies and exploring new applications for sludge, we can minimize waste and reduce the environmental footprint of the paper industry. Additionally, consumer awareness and support for recycling initiatives can help drive demand for more environmentally friendly paper products and encourage the adoption of sustainable practices throughout the supply chain [16], [17].

Steel fibers are a crucial component in modern construction, enhancing the strength and durability of concrete structures. These fibers, typically made from carbon or stainless steel, are dispersed throughout the concrete matrix during mixing, creating a reinforced composite material known as fibre-reinforced concrete (FRC) [18], [19]. Steel fibers act as miniature reinforcements within the concrete, resisting tensile forces and preventing crack propagation. This leads to an increase in

flexural strength, allowing the concrete to withstand greater loads without fracturing. The presence of steel fibers enhances the toughness of concrete by absorbing energy and deflecting cracks. This property is particularly beneficial in applications where impact or dynamic loading is a concern, such as industrial floors, pavements, and bridge decks [20]. Concrete tends to shrink as it cures, which can result in the formation of shrinkage cracks. Steel fibres help mitigate this issue by providing internal restraint, reducing the likelihood of crack formation and minimizing the risk of water ingress and corrosion of embedded reinforcement [21], [22]. By reinforcing the concrete matrix, steel fibers contribute to the overall durability of structures, improving resistance to environmental factors such as freeze-thaw cycles, chemical exposure, and abrasion. This extends the service life of concrete elements and reduces maintenance requirements over time. The addition of steel fibers allows engineers to optimize the design of concrete structures, potentially reducing the need for conventional reinforcement such as rebar or mesh [23], [24]. This can lead to cost savings and greater design flexibility, especially in complex or innovative architectural projects. Steel fibers come in various shapes, sizes, and configurations, allowing engineers to tailor their properties to specific project requirements. Common types include

hooked-end fibers, straight fibers, crimped fibers, and microfibers, each offering unique benefits in terms of bond strength, ductility, and dispersion within the concrete matrix. Overall, steel fibers play a vital role in enhancing the performance and longevity of concrete structures, offering a cost-effective and sustainable solution for a wide range of construction applications. As the construction industry continues to evolve, the utilization of fibre-reinforced concrete is expected to become increasingly prevalent, driving innovation and advancements in structural engineering practices [25]–[29].

The goal of this experiment is to ascertain how well (10%) Hypo sludge performs in hardened concrete qualities in lieu of cement.

2. Experimental Program

2.1. Material

The various materials used in the preparation of concrete are cement, sand, cement coarse aggregates, Steel fibres, Plastic fibres, hypo sludge and water.

2.1.1. Hypo Sludge

Waste material from the paper industry is called hypo sludge. Concrete is made with it instead of cement, and its chemical and physical characteristics have been studied. Now that natural resources are scarce, air pollution and other

environmental issues result from the usage of construction materials. It turns into a cutting-edge substance that supports green technologies. The silica and magnesium characteristics lead it to behave like cement. Concrete sets more quickly thanks to the silica and magnesium in it. Hypo sludge's chemical composition is shown in Table 2, while its physical characteristics are displayed in Table 1.

Table 1 Typical physical properties of hypo sludge

Property	Value
Maximum particle size	0.300mm
Gradation (75% passing)	0.030mm 4600–14000
Specific surface (cm ² /g)	2.7–2.9
Specific gravity	

Table 2 Typical chemical composition of hypo sludge

Compound	Percentage composition
Calcium oxide (CaO)	47.57
Silicon oxides (SiO ₂)	5.2
Aluminum oxide (Al ₂ O ₃)	0.1
Iron oxide (Fe ₂ O ₃)	0.64 6.25

Magnesium oxide (MgO)	0.17 38.25
Sulfur oxide (SO ₃)	
Loss on ignition (LOI)	

2.1.2. Cement

Ordinary Portland Cement (43 Grades) which is easily available in the market is used.

2.1.3. Steel Fibers

Iron wires of diameter 1-2mm and length 5cm were used in concrete as fibre reinforcement.

2.1.4. Plastic Fibers

The length of fibres was kept at 35 mm and the breadth was 1mm.

2.1.5. Fine Aggregate

The natural river sand available in the local market passes through a 2.36mm sieve with a specific gravity of 2.57. Conforming to Zone III.

2.1.6. Coarse Aggregate

Crushed granite conforming to IS 383 - 1987 is used in this study. Coarse aggregates of sizes 20mm and 10mm are used and the specific gravity is 2.42.

2.1.7. Water

Water is an important ingredient of concrete as it actively participates in chemical reactions with

cement, clean portable water which is available on our college campus is used

2.2. Mix Proportion

The mixture proportion for the controlled concrete of M20 grade was used as per IS 10262-2009. Table 3 depicts the mix composition of concrete constituents.

Table 3 Mix proportion

Percentage of cement replacement	10
Percentage of fine aggregate replaced with plastic fibre	3
Percentage of coarse aggregate replaced with steel fibre	1
Cement (Kg)	7.5
Hypo Sludge (Kg)	0.82
Fine Aggregate (Kg)	13.6
Coarse Aggregate (Kg)	28.1
Water (Kg)	4.1
W/C ratio	0.5

3. Methodology

For this study, 10% OPC replacement levels using Hypo Sludge were selected. The M-20 grade of concrete was used, and batching was done by weighing each component of the concrete in accordance with the predicted amount, using a mix ratio of 1:1.5: 3. After that, the ingredients were

properly combined to create a homogenous mixture. After adding water, the mixture was done once more. After compacting and leaving the newly mixed concrete in the 150 mm moulds for a full day, testing was conducted. At 7, 14, and 28 days old, compressive specimens were tested.

4. Results and Discussion

4.1. Compressive Strength

Table 4 presents values for compressive strength. Concrete was tested at seven, fourteen, and twenty-eight days of age to determine its compressive strength. The cubes were put to the test in the structure's lab utilising a 2000KN capacity Compression Testing Machine (CTM). 10% of the Hypo Sludge replacement yields the maximum compressive strength. In Hypo Sludge, there are a lot of contaminants, including free lime and alumina. The compressive strength of various ages of concrete is presented in Table 4. Both samples' compressive strengths at various ages are displayed in Fig. 1.

Replacement of Plastic fibers %			3	3
Replacement of Hypo Sludge %			10	10
Average Ultimate	Compressive strength (N/mm ²)	(7 days)	8.71	8.93
		(14 days)	17.82	19.3
		(28 days)	25.82	26.8

Table 4 Compressive strength test results in concrete at different ages

Serial no.	1	2
Name of cube sample	S 1	S 2
Replacement of Steel fibres %	1	1

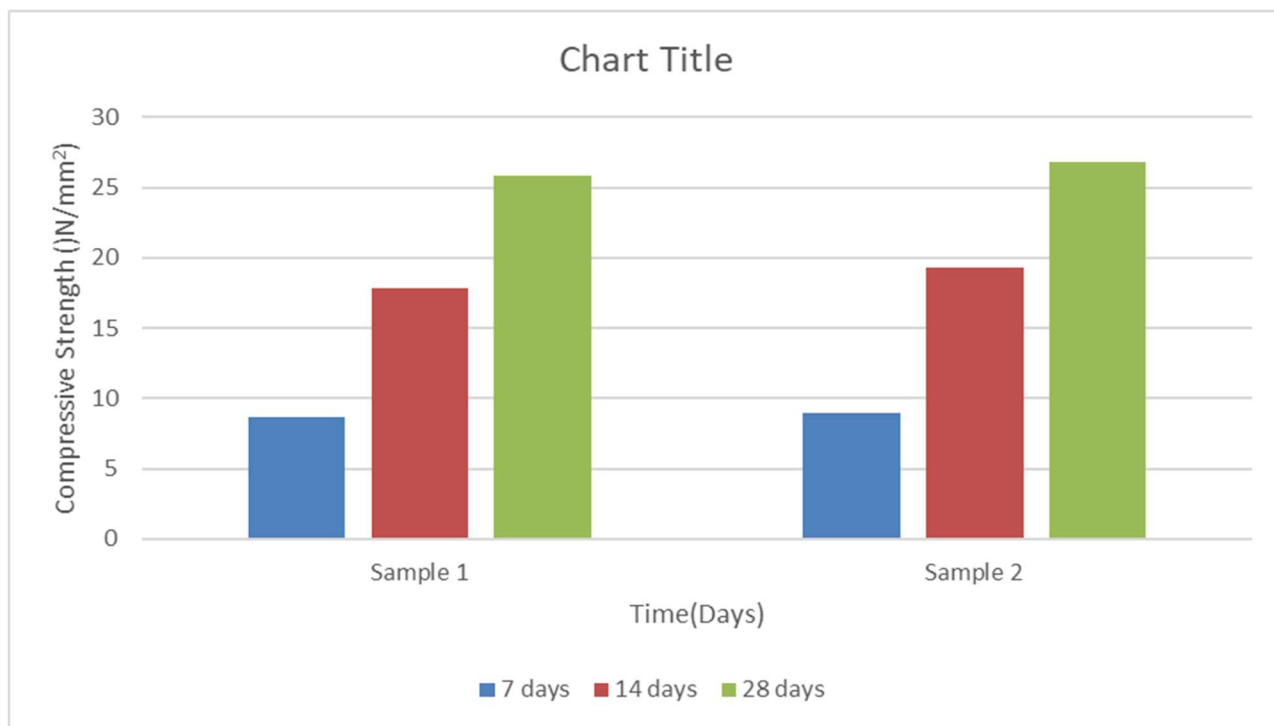


Figure 1 Relationship between compressive strength and 10% of Hypo Sludge, 1% Steel fibre 3% Plastic fibre at age of 7, 14 and 28 days.

5. Conclusions

Using Hypo Sludge in place of certain OPC in a series of trials on concrete, this study investigated the effects of the addition. In a proportion of 10% of the cement's dry weight, Hypo Sludge was utilised to partially replace OPC. As per applicable IS-code practice, the experiments were carried out on concrete of M-20 grade. It is possible to make the following conclusion from the test findings found in this study.

1. According to the findings of the compressive strength test, the typical concrete exhibits a similar strength.

2. Because of the contaminants, such as free lime and other unprocessed minerals, included in Hypo Sludge, strength is decreased when it is added.
3. But even with a 10% replacement, the strength attained with the Hypo Sludge mix hardly satisfies the desired strength.

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